



# **Final Report**

## **Shipboard Tests of the Hamworthy AQUARIUS™ UV Ballast Water Treatment System (Filtration and UV)**

**for Type Approval according to Regulation D-2  
and the relevant IMO Guideline (G8)**

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**Final report of the shipboard tests of the  
Hamworthy AQUARIUS™ UV  
Ballast Water Treatment System  
(Filtration and UV)  
for Type Approval according to Regulation D-2  
and the relevant IMO Guideline (G8)**

**(October 2011 – April 2012)**

**Shipboard tests onboard MV *Twister***

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# 1. Introduction

The three shipboard test cycles to test the performance of the Hamworthy AQUARIUS™ UV ballast water treatment system consisting of filtration and UV, developed by Hamworthy, Poole, UK were undertaken on three voyages of the bulker MV *Twister* between October 2011 and April 2012. The vessel details and the dimensions of both test tanks (the control and treated tanks) are shown in Table 1. For the location of the test tanks see Fig. 1.

Table 1. Main dimensions of the test vessel and tank details.

Vessel name	Twister
IMO number	9507594
Flag	Netherlands
Class	B.V
Vessel type	Tanker
Length overall	99.95 m
Gross Tonnage	2,410 t
Total ballast water capacity	1,452 m <sup>3</sup>
Number of ballast tanks	17
Number of ballast pumps	2
Capacity of ballast pump	125 m <sup>3</sup> /h (for each pump)
Number of ballast water treatment systems installed	1
Treatment capacity for this vessel	250 m <sup>3</sup> /h
Control tank	Wingtank (SB 7)
Control tank capacity	112 m <sup>3</sup>
Treated tank	Wingtanks (SB 3 and PS 3)
Treated tank capacity	157m <sup>3</sup>

The test ship operates on a spot charter market in Europe and frequently calls for ports in Germany, the Netherlands, United Kingdom and Norway.

The BWMS installed onboard MV *Twister* is a Hamworthy AQUARIUS™ UV ballast water treatment system with a treatment rated capacity (TRC) to treat 250 m<sup>3</sup>/h. During the tests, both ship's ballast pumps were used in parallel so that the treatment rated capacity matched to the flow rate of the ships' pumps. The treatment system was installed in 2011, and it is fully implemented and integrated into the ballast system of the vessel.

During all G8 test cycles both the control tank and the treated ballast tanks, were filled and emptied as much as possible and this was conducted in sequence.



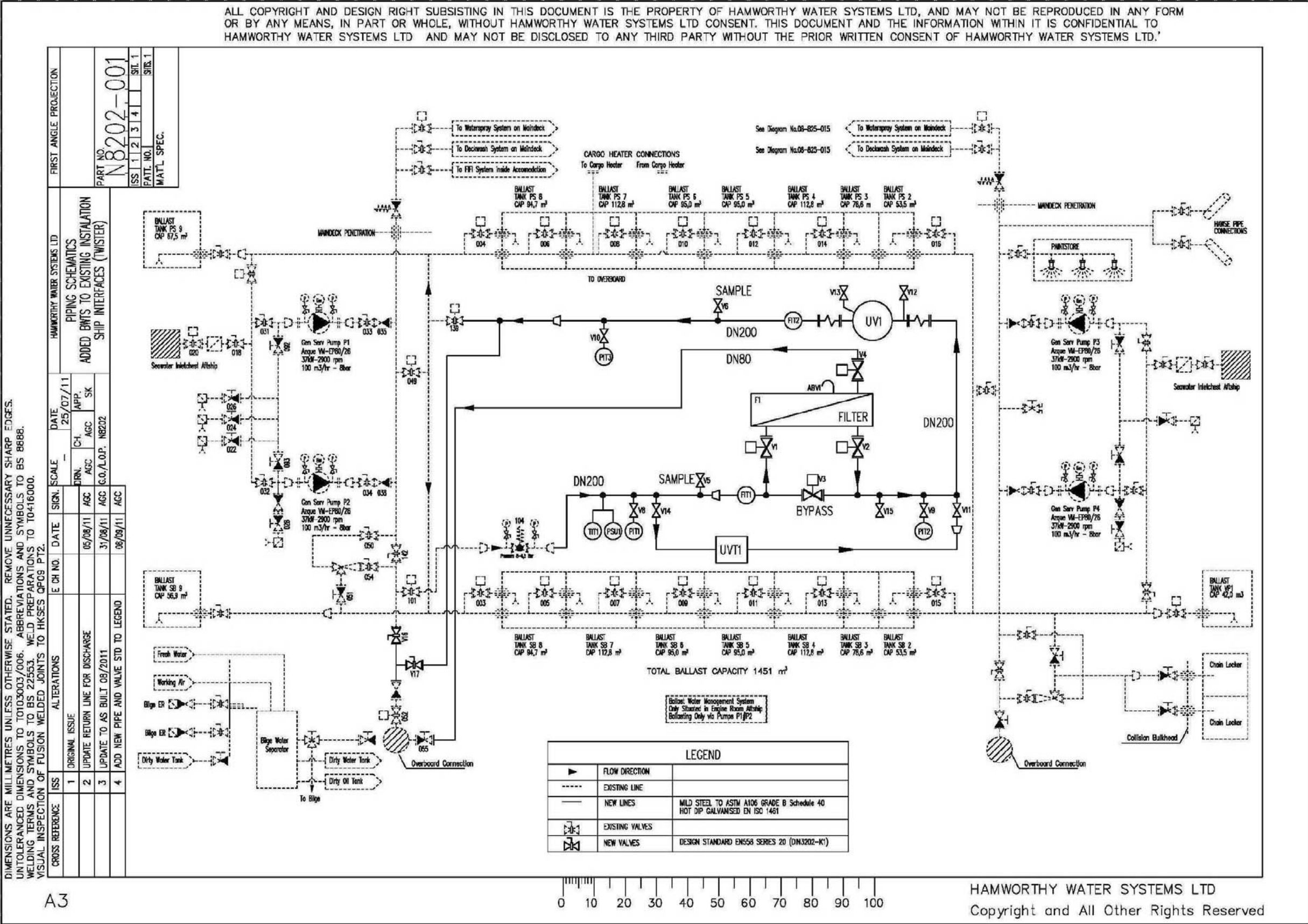


Figure 1 Tank plan of the test vessel *Twister*. The tanks SB 3 and PS 3 were used for the treated water tests and the SB 7 as the control tank.

All samples were taken during the entire ballast water uptake and discharge time, i.e. during the entire pumping event. This approach most likely resulted in a more accurate organism density measurement compared to just taking sequential sub-samples during parts of the ballast water pumping operation (e.g. in the beginning, middle and end of the pumping time), because, when taking sequential samples, organism rich water layers may be missed during the sampling event.

The ballast water was taken up in the following regions:

- Test cycle 1, uptake Krefeld, Germany, discharge Rotterdam, The Netherlands;
- Test cycle 2, uptake Grangemouth, UK, discharge Tees Port; and
- Test cycle 3, uptake Krefeld, Germany, discharge Karsto, Norway.

The holding time of the ballast water in the tank between uptake and discharge was between ca. 22 and 64 hours (Fig. 2).

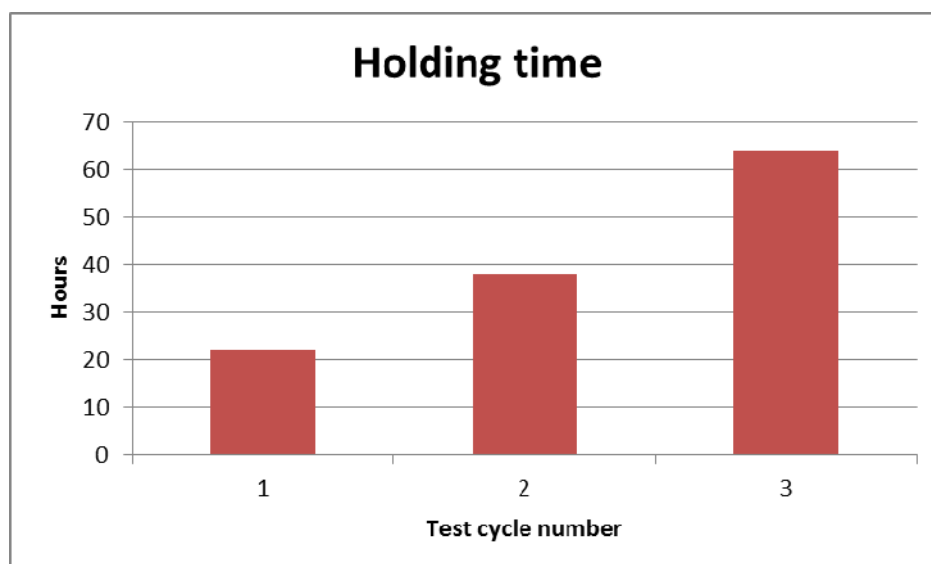


Figure 2. Approximate in-tank holding time of the ballast water between uptake and discharge during all three test cycles.

During all test cycles all samples were taken by sampling team members of GoConsult, Hamburg, Germany.

The chain of custody was guaranteed as the samples to be delivered to the land-based laboratories were transported by GoConsult staff so that no external manipulation was possible.

## 2. Sampling scenario

As shown in the onboard sampling protocol (Gollasch 2011), multiple HydroBios ballast water sampling kits were used during each test cycle. The ballast water samples were collected by using such sampling kits in parallel. The relatively short port times of this vessel did not permit sample processing onboard. Instead the samples were transported to hotel rooms and were processed on land.

- Plankton organisms larger than 50 micron in minimum dimension were analysed directly after sampling.
- The sample processing of indicator microbes *E. coli* and *Enterococci* samples was also conducted directly after sampling and the incubation time was completed on land.
- Cholera bacteria samples were prepared for later analysis by IBEN, Bremerhaven, Germany.
- The samples for plankton less than 50 µm in minimum dimension and greater than or equal to 10 µm in minimum dimension and the phytoplankton below 10 micron in minimum dimension were prepared directly after sampling, the samples were stored in a fridge and the samples were analysed by NIOZ, Texel, the Netherlands.

Procedures for sample processing as outlined in the test protocol (Gollasch 2011) were followed. The protocol was prepared in line with the most up-to-date version of the IMO Guideline G8 *Guidelines for the Approval of Ballast Water Management Systems* (IMO G8, 2008).

The required number of samples and their volumes for one test cycle according to the IMO G8 Guidelines are given in Table 2.

Table 2. Number of samples and their volumes for one test cycle according to G8. The paragraph numbes given refer to paragraphs of the IMO G8 Guidelines.

Sample purpose	Treated tank	Control tank	
	discharge (para 2.2.2.6.2 and 2.2.2.6.3)	uptake (para 2.2.2.6.1, 2.2.2.6.3 and 2.2.2.9)	discharge (para 2.2.2.6.1 and 2.2.2.6.3)
Environmental parameters <sup>1</sup>	1 sample (not required in G8)	1 sample	1 sample (not required in G8)
>50 µm <sup>2</sup>	3 x >1000 L	1 x >1000 L	1 x >1000 L
<50 to >10 µm	3 x >1 L	1 x >1 L	1 x >1 L
Bacteriae	3 x >500 ml	1 x >500 ml	1 x >500 ml (not required in G8)

<sup>1</sup> Temperature, salinity, total suspended solids and particulate organic carbon, see G8, Annex, Part 2, paragraph 2.2.2.9

<sup>2</sup> There is an inconsistency and unclear wording in G8 regarding the uptake sample of the treated line. G8, Annex, Part 2, paragraph 2.2.2.5 *Valid tests are indicated by uptake water, for both the control tank and ballast water to be treated, with viable organism concentration...* but 2.2.2.6 *Sampling regime* sets only requirements for the discharge of treated water. To be on the safe side samples during uptake of the treated water are therefore taken and processed.

The following samples were taken and processed in addition to the requirements of IMO Guideline G8:

- Analysis of environmental and biological parameters of the uptake treated water;
- Analysis of environmental parameters of the discharged treated water;
- Analysis of environmental parameters of the discharged control water;
- Analysis of bacteriae of the discharged control water; and
- Analysis of phytoplankton organisms below 10 micron in minimum dimension.



### **3. Results**

Results regarding environmental parameters and the biological analysis of the samples are shown in the following tables separately per each of all three test cycles. As stated above more environmental parameters and more biological analysis than required by the IMO G8 Guidelines were conducted.

#### **Environmental parameters**

The sample processing revealed environmental parameters as expected to occur in the ballast water uptake regions.

#### **Biological results**

The results show that the water treated with the Hamworthy AQUARIUS™ UV ballast water treatment system complied with the standards in Regulation D-2 of the IMO Ballast Water management Convention (IMO 2004). This applies for all tested organism groups during all tests of the treated water upon discharge.

The minimum intake concentrations of organisms for valid tests according to the IMO G8 Guidelines were met in all test cycles.

During all test cycles for all organism groups, including the phytoplankton organisms below 10 micron in minimum dimension which were processed in addition to the requirements of IMO, the D-2 standard was met at discharge of the treated water.

## Test Cycle Report, Test Cycle 1

Date and time for ballast water **uptake**: 21.10.2011, 10.47 to 12.48h

Position of ship during start of ballast water uptake:

- in Port of Krefeld.
- Water depth ca. 4 m.

Date and time for ballast water **discharge**: 22.10.2011, 09.49 to 10.44

Holding time of ballast water between uptake and discharge: approximately 22 hrs.

Weather conditions during the test: good.

**Table 3. Results of Test Cycle 1.**

(nd = not detectable).

Parameter	Unit	Uptake water			Discharge water						
		control	IMO	before treatment	Control	IMO	Treated			aver. #1-#3	IMO
							# 1	# 2	# 3		
Temperature	°C	12.6	-	12.8	12.6	-	12.5	12.5	12.5	-	-
Salinity	psu	0.3	-	0.3	0.9	-	0.4	0.4	0.4	-	-
POC *	mg/l	12.4	-	30.8	9.2	-	8.4	6.8	7.6	-	-
TSS *	mg/l	25.7	-	35.5	13.7	-	13.1	12.1	12.0	-	-
Sample vol. >50 µm	Litres	1082	>1000	1337	1035	>1000	1154	1153	1203	-	>1000
Sample vol. 50-10 µm	Litres	7	>1	7	7	>1	7	7	7	-	>1
Sample vol. bacteria	Litres	1	>0,5	1	1	-	1	1	1	-	>0,5
Organisms >50µm	org./1m³	10444	>90	5360	3849	>10	nd	10.8	nd	3,6	<10
Organisms 10-50µm*	org./1ml	15774	>90	20924	10451	>10	nd	nd	nd	nd	<10
Organisms 6-7µm*	org./1ml	2128	-	2093	1524	-	nd	nd	nd	nd	-
Organisms ca. 4 µm*	org./1ml	772	-	846	341	-	nd	nd	nd	nd	-
<i>Escherichia coli</i>	cfu/100ml	110	-	70	40	-	nd	nd	nd	nd	<250
Intestinal <i>Enterococci</i>	cfu/100ml	nd	-	nd	nd	-	nd	nd	nd	nd	<100
<i>Vibrio cholerae</i> **	cfu/100ml	nd	-	nd	nd	-	nd	nd	nd	nd	<1

\* Samples analysed at NIOZ, Texel. \*\* Samples analysed at IBEN, Bremerhaven.

## Test Cycle Report, Test Cycle 2

Date and time for ballast water **uptake**: 03.12.2011, 19.46 to 21.24h

Position of ship during start of ballast water uptake:

- in Port of Grangemouth.
- Water depth ca. 4 m.

Date and time for ballast water **discharge**: 05.12.2011, 11.06 to 12.50

Holding time of ballast water between uptake and discharge: approximately 38 hrs.

Weather conditions during the test: good.

**Table 4. Results of Test Cycle 2.**

(nd = not detectable).

Parameter	Unit	Uptake water			Discharge water						
		control	IMO	before treatment	Control	IMO	Treated			aver. #1-#3	IMO
							# 1	# 2	# 3		
Temperature	°C	9.1	-	9.1	8.8	-	8.5	8.5	8.5	-	-
Salinity	Psu	26.8	-	26.7	26.9	-	26.9	26.9	26.9	-	-
POC *	mg/l	8.6	-	7.0	8.0	-	6.8	8.0	8.4	-	-
TSS *	mg/l	22.2	-	17.6	20.6	-	18.6	19.6	20.8	-	-
Sample vol. >50 µm	Litres	1949	>1000	1300	1623	>1000	1766	1745	1745	-	>1000
Sample vol. 50-10 µm	Litres	7	>1	5	7	>1	7	7	7	-	>1
Sample vol. bacteria	Litres	1	>0,5	1	1	-	1	1	1	-	>0,5
Organisms >50µm	org./1m <sup>3</sup>	657	>90	731	200	>10	nd	nd	3.6	1.2	<10
Organisms 10-50µm*	org./1ml	316	>90	172	172	>10	nd	nd	nd	nd	<10
Organisms 5-10µm*	org./1ml	97	-	104	154	-	nd	nd	nd	nd	-
Organisms ca. 4 µm*	org./1ml	103	-	153	140	-	nd	nd	nd	nd	-
<i>Escherichia coli</i>	cfu/100ml	67	-	56	49	-	nd	nd	nd	nd	<250
Intestinal <i>Enterococci</i>	cfu/100ml	60	-	25	35	-	20	nd	nd	6.7	<100
<i>Vibrio cholerae</i> **	cfu/100ml	nd	-	nd	nd	-	nd	nd	nd	nd	<1

\* Samples analysed at NIOZ, Texel. \*\* Samples analysed at IBEN, Bremerhaven.

## Test Cycle Report, Test Cycle 3

Date and time for ballast water **uptake**: 06.04.2012, 10.12 to 11.43h

Position of ship during ballast water uptake:

- in Port of Krefeld.
- Water depth ca. 4 m.

Date and time for ballast water **discharge**: 09.04.2012, 03.47 to 05.06h

Holding time of treated ballast water between uptake and discharge approximately 64 hours.

**Table 5. Results of Test Cycle 3.**

(nd = not detectable).

Parameter	Unit	Uptake water			Discharge water						
		control	IMO	before treatment	Control	IMO	Treated			aver. #1-#3	IMO
							# 1	# 2	# 3		
Temperature	°C	11.5	-	11.3	7.2	-	6.6	6.6	6.6	-	-
Salinity	Psu	0.3	-	0.3	0.3	-	0.3	0.3	0.3	-	-
POC *	mg/l	22.5	-	26.0	10.5	-	7.3	8.0	7.5	-	-
TSS *	mg/l	40.5	-	38.2	40.3	-	19.8	26.5	19.8	-	-
Sample vol. >50 µm	Litres	1394	>1000	1454	1388	>1000	1521	1658	1398	-	>1000
Sample vol. 50-10 µm	Litres	6	>1	6	6	>1	6	6	6	-	>1
Sample vol. bacteria	Litres	1	>0,5	1	1	-	1	1	1	-	>0,5
Organisms >50µm	org./1m³	10732	>90	11431	9697	>10	nd	9.0	5.1	4.7	<10
Organisms 10-50µm*	org./1ml	4450	>90	6140	2484	>10	nd	nd	nd	nd	<10
Organisms 5-10µm*	org./1ml	1840	-	2068	2344	-	nd	nd	nd	nd	-
Organisms 1-5 µm*	org./1ml	264	-	449	771	-	nd	nd	nd	nd	-
<i>Escherichia coli</i>	cfu/100ml	18	-	10	22	-	nd	nd	nd	nd	<250
Intestinal <i>Enterococci</i>	cfu/100ml	90	-	50	15	-	nd	nd	nd	nd	<100
<i>Vibrio cholerae</i> **	cfu/100ml	nd	-	nd	nd	-	nd	nd	nd	nd	<1

\* Samples analysed at NIOZ, Texel. \*\* Samples analysed at IBEN, Bremerhaven.

## 4. Discussion of the results

The Hamworthy AQUARIUS™ UV ballast water treatment system was intensively tested during the three test voyages on which three test cycles were undertaken in total (October 2011 and April 2012). The tests were conducted in different environmental water conditions and different seasons resulting in higher and lower organism concentrations in the uptake water. During these tests the system has proven to be very effective to treat organisms in ballast water.

During all onboard tests, sample taking, sample processing and sample forwarding was always conducted as outlined in the agreed sampling protocol (Gollasch 2011).

**The treated water at discharge of all test cycles met the organism concentration limits as shown in Regulation D-2 of the IMO Ballast Water Management Convention (IMO 2004).**

Although this report primarily focuses on the organism groups addressed in Regulation D-2, in addition the phytoplankton organisms in the size class below 10 micron in minimum dimension were measured and no living phytoplankton in this category was observed in the treated water at discharge.

## 5. Test validity

### Samples

All required samples were taken to document the abiotic and biotic water conditions during the tests. Further, additional samples were taken and all samples were analysed for more parameters as required by the IMO G8 Guidelines (see above). The minimum water volumes of all sample types, as stated in the IMO G8 Guidelines, were met.

### Biology

The required minimum organism intake concentrations to challenge the treatment system exceeded the required numbers as stated in the IMO G8 Guidelines in all three test cycles.

The organism discharge standards as stated in Regulation D-2 of the IMO Ballast Water Management Convention of 2004, was met at discharge of the treated water in all test cycles.

**Consequently, all three tests are considered as valid tests according to the IMO requirements (Guidelines G8 and Regulation D-2).**

## References

Gollasch, S. 2011. Quality Management Plan and Quality Assurance Project Plan for Shipboard Tests of the Hamworthy Ballast Water Management System. Version 2, 2011-08-22, 58 pp.

IMO 2004. International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004. International Maritime Organization, 13 February 2004. 36 pp.

IMO G8 2008. IMO Guideline G8 Guidelines for the Approval of Ballast Water Management Systems adopted on 10 October 2008 as Resolution MEPC.174(58), 28 pp.